largely developed. Monsieur Porte had kindly offered, in case it could be arranged, to receive a visit to it of the female now in the Society's Gardens, but Mr. Sclater feared that it would be too risky to advise the transport to Paris and back of such an animal.

Amongst the breeding groups of larger animals in the Jardin d'Acclimatation, Mr. Sclater had specially noticed those of *Cervus davidianus* (3 examples), *Oreas canna* (5 examples), *Cobus unctuosus* (5 examples), and *Oryx leucoryx* (3 examples). Mr. Sclater had also examined with great interest a specimen of a beautiful small Wild Cat from Siam, which was quite new to him. It was labelled *Felis minuta*, but was certainly quite different from *Felis javensis* as figured by Elliot ('Felidæ,' plate xxviii.), under which name Mr. Elliot had placed *Felis minuta* of Temminck as a synonym.

The following papers were read:—

1. On the Breeding of the Dragonet (*Callionymus lyra*) in the Marine Biological Association's Aquarium at Plymouth; with a preliminary account of the Elements, and some remarks on the significance of the Sexual Dimorphism.

By Ernest W. L. Holt.

[Received April 18, 1898.]

(Plate XXVI.)

Contents.

I. *Introductory and Historical.*

So far as I am aware the Dragonet furnishes, among Teleostean fishes propagating by pelagic ova, the only known instance of a definite sexual intercourse. Since Savile Kent's account of the pairing appeared rather meagre, I considered it desirable to make further observations, and, with this end in view, commenced to collect as many large specimens as possible in the autumn of 1897. Experience with other marine forms had shown the necessity of acclimatizing the fish to tank life some considerable time before the breeding-season. The Dragonet, locally known as the Sting-

fish or Miller's Thumb, is one of the commonest fish in the Plymouth district, and commences to spawn there, as has been shown by Mr. S. D. Scott and myself [1], in the first month of the year.

A number of females and small undifferentiated males were successfully acclimatized in the autumn and early winter, but no large differentiated males survived. However, two fine specimens were brought in in January, and at once took kindly to their new surroundings. When these males were placed in the tank a female was observed to watch their movements with evident interest. As frequently happens, they spent a considerable time in swimming about the surface of the tank before descending. The female meanwhile swam about at the bottom, following now the movements of one male, now of the other. When one finally descended, the female approached and appeared to smell him. Her curiosity thus satisfied, she took no further notice of him.

I had occasion to be absent from the Laboratory for about a fortnight, ending on the 10th February. No signs of sexual activity were previously observed, and Mr. Smith, the chief Laboratory attendant, who was kind enough to keep watch on the proceedings of the Dragonets during my absence, saw nothing unusual in their behaviour. On the 11th February I found pairing in full progress; but, before giving the results of my own observations, I propose to quote the account given by Savile Kent, who, I believe, is the only writer who has dealt with the subject:—

"The male, resplendent in his bridal livery, swims leisurely round the female, who is reclining quietly on the sand, his opercula distended, his glittering dorsal fins erect, and his every effort being concentrated upon the endeavour to attract the attention and fascinate the affections of his mate . . . . . The female, at first indifferent, becomes at length evidently dazzled by his resplendent attire and the persistency of his wooing. She rises to meet him, the pair—so far as is practicable with fishes—rush into each other's arms, and with their ventral areas closely applied ascend perpendicularly towards the surface of the water. In connection with these manœuvres it may safely be predicted that the ova are extruded and fertilized, but in the limited depth of water of an aquarium tank the matrimonial tour cannot, apparently, be sufficiently prolonged to ensure the consummation of this act; the fish, after reaching the surface, being projected by their previously gained impetus slightly above it, when, falling apart, they sink slowly to the bottom, and the process, after short intervals, is repeated. It is, however, by no means impossible nor even improbable that the fertilization of the eggs in *Callionymus* may take place while the fish are above the surface of the water, as has actually been recorded by Alexander Stenzel in the Nase or Zupe, *Chondrostoma nasus*." (Savile Kent, Handbk. Gt. Intern. Fish Exhib. Lond., i. 1883, p. 128.)

[1] Holt and Scott, Journ. M. B. A., n. s., v. p. 156, 1898.

In connection with the preceding remarks, and also in 'Nature' (viii. 1873, p. 264), the author draws a comparison between the secondary characters and courting behaviour of the male *Callionymus* and those of birds, which has been dignified by a reference in Darwin's 'Descent of Man.' With regard to his account of the pairing, it appears to be of a popular character, and, as the subject is rather a delicate one, any criticism of its inadequacy would be ungracious. If, however, I may judge from my own experience, the account is so inaccurate in some details of importance as to warrant a full redescription.

II. *Secondary Sexual Characters.*

It is now matter of common knowledge that, while young Dragonets of either sex closely resemble each other both in colour and conformation [1], the male acquires, as its size increases, very well-marked secondary sexual characters. It will be convenient to briefly recapitulate the most striking differences, since these will be found to play an important part in the behaviour of the two sexes when pairing.

In the female, throughout life the first dorsal fin is very short. The second dorsal and the anal are of moderate proportions, their posterior rays not being produced in such a manner as to reach the caudal fin when depressed. The proportions of the head undergo no marked metamorphosis. The genital aperture is at no time produced into an elongated papilla. The colours of the dorsal surface are brown or reddish brown, barred and mottled with lighter and darker markings, and closely resembling the bottom on which the fish may be resting. In young examples on bright gravel the general colour may be diversified with purple, green, and crimson. The ventral surface is devoid of pigment.

The male, on the contrary, acquires with growth a more elongated snout. The first dorsal fin becomes greatly elongated. The second dorsal and the anal increase in size, especially their posterior rays, which ultimately reach, when depressed, beyond the origin of the caudal fin. There is a distinct genital papilla, visible even in specimens only two inches in length, and conspicuously elongated in large fish. The metamorphosis of the head and fins appears to be of a gradual nature, though perhaps more rapidly accomplished during the later period of growth. It is not constantly related, in its ulterior development, to a fixed size, nor to the attainment of sexual maturity.

Pari passu with these structural differentiations appears a striking change in the coloration. While the back retains the marbled brown markings, the front and sides of the head, the sides of the trunk, and the pelvic, dorsal, and caudal fins become decorated with yellow and blue bands. I need not particularize these since the drawing exhibited (Plate XXVI.) gives an accurate representation

[1] Inconspicuous differences exist from an early age (Fries, *cf.* Smitt, Hist. Scand. Fish. ed. 2, i. p. 277).

of a fully mature male, such individual differences as are met with in the number and distribution of the bands being of no importance here. The bands of the first dorsal are less frequently a pale blue, the colour manifesting itself rather often in the detached markings near the base of the fin. The eye, reddish brown or cupreous in females and young males, becomes in large breeding males of a brilliant metallic blue-green, most readily comparable to the palest tint present in the ocellus of a peacock's "tail" feather. On the ventral surface the throat, the underside of the pelvics, and the anal fin become adorned with black pigment, the anal occasionally showing an additional bluish tinge.

The colour-change of the eye appears to be of a seasonal character. The other changes are of a more permanent nature, though the brilliant coloration shown in the drawing (Plate XXVI.), especially in so far as regards the yellow bands of the body, is of comparatively brief seasonal duration. As in the case of the structural characters, the full development of the coloration-change is not necessarily achieved before the fish is fully mature. Thus Dr. G. Johnston (Zool. Journ. iii. p. 336) records a "Sordid"[1] Dragonet with milt, and Mr. G. A. Boulenger has shown me a male, with ripe milt, in which the secondary characters are only slightly developed[2].

This is by no means surprising, since males of *Arnoglossus laterna*[3] and *Coris julis*[4], which, as I believe, undergo a sexual dimorphism exactly parallel to that of *Callionymus*, are frequently mature in the undifferentiated livery. It is, I suppose, unnecessary to adduce instances among the higher animals in which the sexual maturity of the male is accomplished before the full development of the secondary differentiations.

The smallest sexually mature male Dragonet which has come under my notice measures 16 cm. ($6\frac{1}{4}$ inches). The extremity of the first dorsal ray reaches the base of the seventh ray of the second dorsal fin. The blue and yellow coloration is present, but the yellow especially is much less brilliant than that of large males taken at the same time. There is very little black pigment on the throat, and only the hinder rays of the anal are somewhat dark. The testes are small, but contain many advanced and a

[1] It is perhaps unnecessary to state that the Sordid Dragonet, *C. dracunculus*, comprising females and undifferentiated males, was once held to be distinct from the Gemmeous Dragonet, *C. lyra*; the latter term being reserved for fully-developed males.

[2] Day (Fish. Gt. Brit. i. p. 176) quotes an observation of the Rev. G. Harris, who stated that he had found hard roe in a "Gemmeous" Dragonet. I can only associate myself with the compiler's comment that this observation is interesting, if correct.

[3] *Cf.* Cunningham, Proc. Zool. Soc. 1890, p. 540; Holt and Calderwood, Sci. Trans. R. Dub. Soc. ser. ii. v. 1895, p. 488.

[4] The specific identity of *C. julis* and *C. giofredi* has been denied by Gourret in the most positive manner (Ann. Mus. Mars. iv. 1893, no. 3). I have re-examined the question at Marseilles, where Gourret's material was procured, and can find no support for his conclusions. A note dealing with the subject is now in the press (Ann. Mus. Mars., ser. 2, Bulletin i.).

few ripe and active spermatozoa. Another male, taken in company with the last, is 15·4 cm. ($6\frac{1}{8}$ in.) in length. In structural differentiation it is nearly as advanced as the last, the first dorsal ray reaching the fourth of the second dorsal fin; but the coloration differs from that of two females of about the same length only in that the dark spot of the first dorsal is bounded anteriorly by the third instead of the second ray, a more or less constant sexual distinction. In this male the testes contain no advanced spermatozoa. It would appear, therefore, that the coloration is more intimately associated with the maturity of the genital organs than is the structural differentiation.

Another sexually immature male, 18·3 cm. ($7\frac{3}{16}$ in.) long, supports the same conclusion. The coloration is quite undifferentiated, though the first dorsal ray nearly reaches the eighth of the second dorsal. The variation of size in relation to sexual maturity is in no way remarkable.

Smitt (Hist. Scand. Fish. ed. 2, i. p. 273) notes that the male, which reaches a length of 30 cm., is much larger than the female. The latter has not been observed, by Scandinavian naturalists, to reach 25 cm.[1] This statement is in general accordance with my own experience of the species. As a matter of fact the difference in size, among the larger specimens, is to some extent due to the greater length of the snout and caudal fin in the male. Thus a male and female measure respectively 24 and 21·7 cm., but in regard to the distance from the front of the eye to the origin of the caudal fin are of exactly the same length.

In the mature condition, at all events, males appear to be much more abundant than females. On two occasions a trawler has brought me what purported to be his whole catch of Dragonets. In one catch there were 95 males and 21 females, in another 72 males and 1 female. The actual proportions may be to some extent obscured by the smaller females escaping through the meshes or being overlooked by the fishermen, but the great discrepancy cannot be altogether accounted for in this way, and a general preponderance of males is borne out by my own trawling experience. A similar numerical proportion of the sexes obtains, as first pointed out by Cunningham, in *Arnoglossus laterna*, at least among the large specimens on the offshore grounds. Here also the male is the larger fish. Among Teleosteans the female is nearly always the larger and the more abundant sex. The relations of size are here reversed, and, if food competition severely taxes the weaker individuals, it is not unnatural that the relations of number should conform. Without the necessity of supposing (without proof) that the feebler members are actually starved out in the early stages of life-history, we arrive at the same result if we allow that sex is largely influenced by nutrition. It would appear that a plentiful nutrition favours the production of female individuals. In the case of *Callionymus*, if the sex is determined,

[1] The smallest ripe female which I have seen measured 16·8 cm. ($6\frac{5}{8}$ in.). A specimen of 14·2 cm. was very nearly ripe.

as Stolzmann considers in birds [1], by ovarian nutrition, it is obvious that the conditions are decidedly adverse to a preponderance of female offspring. Among insects it is known that sex is, or in some cases may be, determined by the nutrition of the larva. It is difficult to believe that this is the case in Teleostean fishes, since we might expect that the female sex would invariably preponderate in size and number. Valuable information might accrue from the experimental feeding of salmon or trout larvæ; our present control of marine forms, and especially of such as propagate by minute pelagic eggs, does not promise much in this field of research.

Although the subject does not concern the sexual dimorphism, a few words are necessary on the position of the eyes in order to explain my figures. In dead specimens the eyes are sunk into the sockets and scarcely project above the general level of the top of the head. They are faithfully presented in such condition in all the figures of *C. lyra* which I have seen. In life, however, the eyes project boldly above the cephalic contour as indicated in my figure 1 [2]. They are not retracted on alarm, but only when the fish has buried itself in the sand or gravel. Retraction is evidently effected by the eye-muscles. Protraction must be ascribed to the elasticity of the membranous wall of the orbit and of a large but very delicate *recessus orbitalis* [3]. This structure communicates with the membranous cavity, as may be demonstrated by injections, below the centre of the eye. It is so thin-walled that I have not found it possible to make satisfactory dissections. Lying for the most part immediately under the skin, externally to the eye, it dips anteriorly below the spatulate part of the great lachrymal scute. Posteriorly it approaches the base of the preopercular trident. In its lateral region it appears broken up into a great number of minute chambers into which the injected fluid does not readily pass. I must acknowledge the assistance of my friend Mr. L. W. Byrne in tracing out this organ. At present our results do not justify a more detailed description.

III. *Courtship and Pairing.*

The Dragonets inhabit a glass-fronted tank, about four feet deep, on the south side of the aquarium. The sides are painted white and the bottom is covered with fine light gravel.

The other inhabitants of the tank are a number of grey mullet, two red mullet, a small bass, some rockling, and sundry crabs and hermits, the latter with their associated anemones, *Adamsia rondeletii* and *A. palliata*.

In February there were two large male Dragonets, with fully-

[1] I must acknowledge my indebtedness to Mr. F. E. Beddard's 'Animal Coloration,' Lond., 1892, p. 277, &c.

[2] Probably some approach to the natural condition is shown by Richardson, in his figure of *C. reevesii* (*C. longicaudatus*, Temm. & Schleg.) in Voy. Sulph., Fish, pl. 36. fig. 1.

[3] *Cf.* P. Z. S. 1894, p. 422.

developed secondary characters. One of these was found to measure 24·75 cm. ($9\frac{3}{4}$ inches). The other appeared to be almost exactly the same size. A female, one of the largest, was 17·15 cm. ($6\frac{3}{4}$ inches) long. There were also a number of fish of about the same size and smaller, including both females and young males.

Previous to the 11th February the Dragonets were sluggish in disposition, frequently burying themselves in the gravel, though active enough at feeding-time. The large males were not observed to display their dorsal fins, though young fish will often raise the first dorsal. The colours of the large males, so far as they could be seen, were not remarkably brilliant.

Entering the aquarium at about 9 A.M. on the morning of the 11th February, I noticed a pair of Dragonets ascending together to the surface of the tank, and found, on observation, that pairing was in full progress. The operation was repeated every day until the 19th February, so that I had ample opportunity of noting the details, which I shall attempt to describe.

While pairing is in progress all the Dragonets in the tank appear to be in a state of great excitement, especially the two large males. These keep darting along the bottom of the tank at short intervals, at the same time exhibiting all their finery. Sometimes the dorsal fins are erected before the fish starts, oftener at the instant of starting, while the mouth is protruded to its utmost, causing the roof of the groove which lodges the ethmoid process of the premaxillæ to be raised nearly or quite to the level of the top of the eyes. The gill-covers are inflated and the hyoid apparatus is depressed, while the pelvic fins are held rigidly forward and outward. The attitude is well shown in my sister's drawing (Plate XXVI.)[1]. The fish scarcely leaves the bottom, the anal fins remaining depressed and out of sight. The motive power is furnished by the pectoral and caudal fins, sometimes by a stroke of the whole tail. The yellow bands are much more brilliant than they were noticed to be before sexual activity commenced. They undergo no change with the elevation of the fins, but retain their extreme brilliance only for the first few days. The blue bands of the side flash out with intense brilliance as the fins are hoisted, but become paler again before they are lowered. This vividness of colour is attained only during the first few days of sexual activity.

The blue bands of the head are but little, and those of the pelvic fin not at all affected when the dorsals are raised. The bands of the latter never attain the same depth of colour as those of the side. Their colour is rather that of a turquoise, while

[1] Van Wright's figure (H. Smitt, Hist. Scand. Fish. ed. 2, pl. xiv.) was painted from life, but the depressed condition of the eyes and the position of the pelvic and anal fins suggest that the outline was taken from a dead specimen artificially arranged. My sister's drawing is a compilation of sketches from life, checked by measurements of a dead specimen of about the same size as the living model.

those of the side approach the deep lustre of a sapphire. I think that the drawing (Plate XXVI.) gives a faithful representation of the colours in their most intense development. These manifestations occupy but a very short time. The whole mouth-apparatus being engaged, it follows that the attitude cannot be maintained beyond the interval of a single respiration. As a rule the mouth is partly retracted and the fins lowered for a time at the end of the respiratory period, but sometimes respiration takes place without the lowering of the fins.

The male fish appears to make its advances in rather a promiscuous manner. Although the Dragonet is keen-sighted and apparently depends chiefly on its eyesight for obtaining food, the male does not seem to be able to see or find the female unless she is quite near him. He darts about, as it appears to me, frequently without any particular object. If other Dragonets, females or young males, are near, he darts at them, driving them off in precipitate flight. My observations lead me to the belief that the courting male cannot distinguish either between females and young males, or between ripe and unripe females except by their response to his advances. Occasionally the two males meet in full splendour. Then one lowers his colours and flies ingloriously; but I have seldom seen anything in the shape of a fight, and have never found wounds that might have been inflicted when I was not watching.

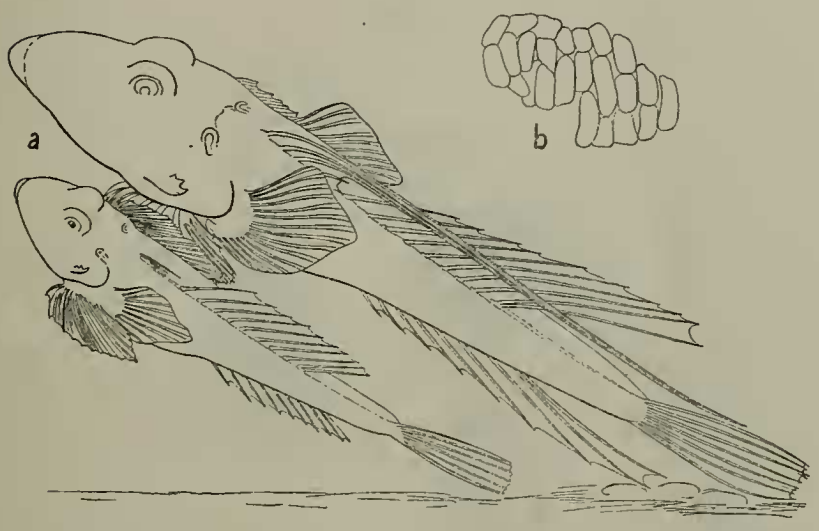
Quite often the male makes a dart when no other fish at all is near, or rushes among the mullet, who are by no means interested in his demonstrations. It may be supposed that on these occasions he is merely advertising his whereabouts to any female that may see him, since he is a conspicuous object, while she is not. When not moving about, the male elevates his head by means of the pelvic fins and moves his eyes in all possible directions, and does not fully retract the protrusible jaw-apparatus until active operations are suspended.

Of the females present in the tank only one, which proved to measure 17·15 cm. ($6\frac{3}{4}$ inches), was on this occasion in breeding order. She makes no demonstrations of a very marked nature, now resting poised on her pelvic fins, now swimming from one part of the tank to another. Her dorsal fins are not raised, and indeed they would not make her much more conspicuous. Now and then a male approaches her and evidently recognizes, perhaps only from her response to his advance, her sex and condition. He proceeds to glide past or circle in front of her, sometimes resting still in front of her with all his bravery displayed. If the two males both approach her at the same time, one is soon put to flight, as we have seen, by what usually appears to be simply a battle of millinery. But, as we shall see later, I have particularly noticed that the spoils are not always to the victor.

Acceptance is denoted by the female swimming to the side of the male, who, as a rule, instantly lowers his fins and retracts his jaws and gill-covers. The two then swim slowly side by side

along the bottom, the female converging on the male. When the two are close together the male gradually raises the fore part of his body off the bottom by the action of his pectorals, at the same time elevating the hind part of his second dorsal and anal. The female, whose pelvics are rigidly expanded, places one of them on that of the male, and squeezes herself snugly into the hollow between his gill-cover and pectoral and pelvic fins. Meanwhile her second dorsal and anal are rigidly erected. The process at this stage is shown in the sketch (fig. 1, p. 289). It is impossible to resist the simile of a lady taking a gentleman's arm.

Fig. 1.

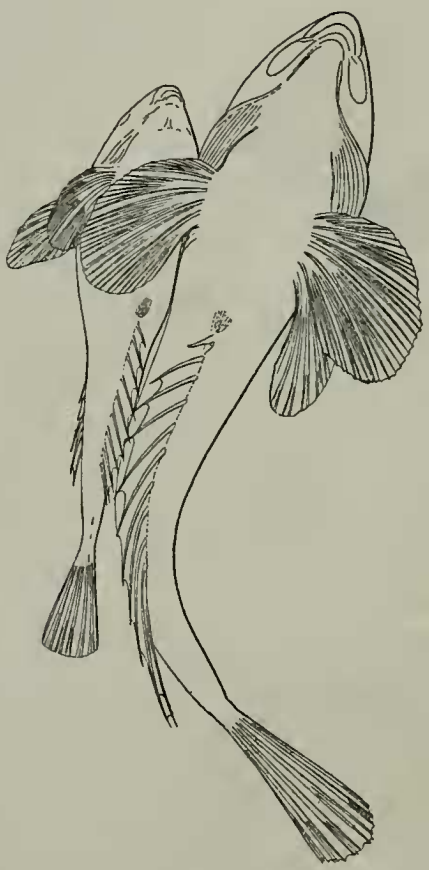


a. Male and female Dragonets preparing to ascend. Reduced three-fifths.
b. Bundle of prismatic bodies. Magnified.

The female once in position, a result which is attained by the action of her pectorals and sometimes her caudal, the male slowly raises himself, and her, to an almost vertical position, and the matrimonial tour, as Savile Kent terms it, commences. So far as I can see, the male actually carries the female up, since her body is held rigidly straight and the movements of her pectorals and, occasionally, of her caudal seem mostly devoted to maintaining herself in position. In ascending the male uses chiefly his pectorals, aided by the caudal and the hinder parts of the second dorsal and anal. I owe to Mr. J. T. Cunningham the suggestion that this function explains why these fins are more elongated, especially in the hinder region, than those of the female. As for the first dorsal, that is evidently for show and not for use; it is kept out of the way, flat on the back.

Once well clear of the bottom, the pair soon assume an absolutely vertical position, and the male, by a sinuous flexure of his trunk, brings his side, for some part of its length, in contact with that of the female, at the same time turning the front part of his anal towards her. and pointing his now elongated genital papilla in the same direction. The female becomes slightly inclined towards him, so that the edges of their anal fins are in contact for some distance. A funnel is thus formed, and, as I suppose, the ova are shot down it from the backwardly-directed genital aperture and fertilized *en passant*, a process which is assisted by the gentle fanning of the first few anal rays of the male. The relations of the pair are shown in the drawing (fig. 2, p. 290). There is, and,

Fig. 2.



Male and female Dragonets in coition. Reduced three-fifths.

from the anatomy of the participators, can be no such apposition of the ventral surfaces as is described by Savile Kent, since such would certainly involve the female quitting her position at the base of the

male's pelvic fin and so losing her hold on his person if not on his affections. As the tank is only four feet deep the pair naturally reach the surface soon, though the upward progress is very slow, since the male, who has most of the work to do, is much hampered by the impossibility of using the tail, his principal organ of locomotion when unhampered by female society. Arrived at the surface the pair occasionally come apart, but more usually continue together, their snouts bobbing in and out of the water, while they wander vaguely about, still endeavouring to ascend[1]. In process of time they lose hold of each other and dart rapidly to the bottom. Sometimes the male, more rarely the female, seems unaware of his or her loss and continues to cruise futilely at the surface. Occasionally one or the other will ascend to the surface alone, so that it is possible that the female assists in the ascent (when the two are together), though I certainly think that she is more concerned in sticking to her partner. The superior size of the male is no doubt of importance.

I cannot positively say that I saw ova extruded. They are very small and practically transparent, and difficult enough to see even under the most favourable circumstances in a tank. It is my impression that I saw them on one occasion. Milt was not extruded by the male in visible quantities, but the milky fluid common to many fishes is not always found in connection with ripe spermatozoa. In any case ova were extruded and fertilized, since they appeared in a net fixed on the overflow port of the tank, and duly hatched out in the jars in which they were placed. Evidently the limited depth of the tank is not, as Savile Kent supposed, a bar to the successful accomplishment of the matrimonial enterprise.

I was able to ascertain that the female takes sometimes the right, sometimes the left pelvic of the male, but whether by accident or design I cannot say. In the ripe condition the ovaries cause a very conspicuous bulge on either side of the posterior part of the abdomen, and it may be that the close apposition of the sides of the male and female assists the latter in the extrusion of the products of whichever ovary is thus subjected to pressure[2].

The first period of reproductive activity lasted, as we have seen, for eight days, commencing, as first observed, on the 11th February. The activity was greatest for the first few days, and the full splendour of the male was only attained during about three or four days. Only one female was engaged. Pairing was observed to take place from 9 A.M. to about 11 A.M. or noon. After this the males ceased to sport and usually buried themselves in the

[1] There is no evidence to show how far the ascent is continued under natural circumstances, but a male has been recorded by Matthias Dunn (in Day's Fish. Gt. Brit. i. p. 176) from a mackerel-net at the surface of 40 fathoms in May. Some examples are still breeding in this month. The species has been taken at a maximum depth of 218 fathoms.

[2] In *Mallotus villosus*, a species propagating by demersal eggs, "two males, one on each side, hold the female, while she rushes with great swiftness on the sandy beach and there deposits her spawn" ('Descent of Man,' p. 331).

gravel. At about 4 P.M. activity recommenced, but in a much less degree. No pairing was observed in the evening, at night, or very early in the morning.

The notes have chiefly been drawn from this period. With a view to further observations I collected as many living Dragonets, of mature size, as possible, and placed them in the tank. All fish of other species, except the rockling, were removed, as they were constantly getting in the way and obscuring the view.

Dragonets are very delicate fish, and large ones are especially difficult to bring in in good condition, since, if they do not die on the way, they often succumb very shortly to injuries they may have received in the net. The caudal fin is particularly liable to abrasion, which almost always proves fatal, the fin sloughing away and the fish dying within a few days. A number of fish were brought in, comprising but a few females, and I believe that all the latter died. I wished to observe the behaviour of a large female, about 23 cm. in length. She appeared fully ripe and was assiduously courted by the males, but made no response, and succumbed in the usual way to injury of the caudal fin.

Pairing was again observed on the 8th March, and continued, somewhat intermittently, for about ten days. Only one female was engaged, and, if not the same individual as paired in the previous month, she was of about the same length, and therefore greatly inferior in size to her partners. There were five males with fully-developed sexual characters, including the two which took part in the proceedings of the previous month. None were in very brilliant colour, and one in particular, belonging, I think, to the original stock, had practically lost all the brilliant yellow of the body-bands. On the 12th March I spent some time in watching the pairing-operations, wishing to obtain some knowledge of the selective proclivities of the female. I shall call the males A, B, C, D, and E. A and B are large; C and D are rather smaller, but as well furnished, both as to colour and differentiation of fins; E is large, but dull in colour. The female may be called G.

A and G ascend together, and come down, quite near each other and near B. B immediately approaches G, and exhibits himself several times to her, just in front of A, who lies still, breathing rather rapidly but making no sign. G accepts B's attention and they are about to ascend, when they lose hold and separate. They very shortly adjust matters and start again. Just as they are leaving the bottom, A rouses himself, and, setting up his fins, darts under them, sweeping their bellies with his first dorsal. They are not disturbed and consummate their tour. In descending G swims off to the neighbourhood of D. I did not see B engaged again on that morning.

Subsequently A and G are about to ascend, when C, who is much smaller than A, approaches and makes demonstrations. A leaves G and sets his fins at C. A few counter-demonstrations ensue, until, when both are in full array, A suddenly darts above

C, striking the first dorsal of the latter about halfway up with his head. The movement is very rapid, the object being, apparently, to strike C's fin with the teeth, which project when the snout is fully protracted. No damage whatever is inflicted, but C runs away. This attack was repeated on another occasion, and appears to be the nearest approach to a fight that ever takes place. In spite of the discomfiture of C, G continued to ascend alternately with the conqueror and the conquered for the rest of the time that I was watching them. I did not see her in the neighbourhood of D. B was quiet after the ascent noted. E, the large dull-coloured fish, made no demonstrations, and seemed only concerned to get out of the way of such males as approached him with fins erect. He finally buried himself in the gravel.

It is difficult to decide, from the above observations, that superior size and strength are of much avail to the male. A, though he defeated C, got no more of G's society than his rival, while B carried her off under his very nose. The system appears, in fact, to be simply promiscuous polyandry, the female coupling with the nearest male who is in a condition to further her object. Among a lot of individual males, including some which are sexually mature but neither very large nor thoroughly differentiated, I imagine that the demonstrations of the large fully-differentiated specimens would achieve the result of driving the smaller and less ornate members from the field; but, among themselves, fully mature males seem to attain no individual advantage, and the female does not care a rap with whom she pairs. However, her involuntary selection of any fully mature male (the small semi-differentiated ones being driven away) must tend to the advantage of the species, if the influence of the male parent is of importance in determining the size and vigour of the offspring.

Savile Kent has compared the courting antics of the male Dragonet to those of the cock in certain of the pheasants. In the main the comparison seems just, though the Dragonet often exhibits his charms in a purely speculative manner, on the chance, as I suppose, of attracting a partner unseen to himself, but of whose presence, somewhere in the vicinity, he is presumably aware. Under similar circumstances the cock pheasant, perhaps, would exert his vocal accomplishments, such as they are. Although we have had mature male Dragonets in the tanks at practically all times of the year, I have never seen them in the full courting attitude except during the breeding-season. Moreover, some mature males kept for a time during the breeding-season in a tank by themselves were not observed to show any signs of sexual excitement, although the maturity of their reproductive organs was demonstrated by their behaviour when transferred to the tank containing the ripe female. It must be a matter of general experience that the domestic barn-door cock "scratches his wing" to younger members of his own sex in a manner exactly similar to that which he employs in endearing himself to the hen which he designs to favour. The old cock can undoubtedly distinguish a

cockerel from a pullet by sight alone. I doubt whether a big male Dragonet has the same power of discrimination with regard to his own species. His demonstrations to young males or unripe females are precisely similar to those which are directed to the mature female, and the result is the same as in the case of poultry—viz., the younger members flee in evident alarm.

IV. *Employment of the Secondary Sexual Characters for purposes not connected with Reproduction.*

During and after the breeding-season the males have been observed to make use of their elongated dorsal fins for purposes quite unconnected with sexual intercourse. I can neither affirm nor deny that their habits are the same at all seasons. After the mullet had been removed from the tank it was first noticed by Mr. Smith (and confirmed by frequent observations of my own) that the mature males elevate their first dorsals in rushing at worms (*Nereis* and *Arenicola*) dropped into the tank. When a bunch of worms is dropped in, all the Dragonets, if not recently fed, assemble to partake. The young ones are always the first on the scene, but the advent of a large male, with dorsals extended, is sufficient to scatter them. It is reasonable to suppose that the display is intended to achieve this object. It is exhibited indifferently by brilliant males and by those whose coloration has decidedly faded. I do not think it unlikely that the fins are displayed with this intent at all seasons; the circumstances have not at other times been so favourable for observation.

Mature males when recently introduced into the aquarium do not display the dorsals, except in the most momentary fashion, when chased about the tank with a net; but when they have remained in a tank for some days undisturbed, the approach of the net is sufficient to ensure the dorsals being fully displayed, and for a period more protracted than I ever observed during courtship. Continued persecution causes momentary intensification of the blue bands of the side, even when the yellow bands have largely faded. The fish, in fact, continues to freely exhibit his secondary characters until he succeeds in darting into a dark corner or burying himself in the gravel. One can hardly hesitate to believe that the fins are hoisted and the colours displayed with a view to the intimidation of the intruder. There is a practical difficulty in the way of testing the truth of this supposition by the behaviour of the Dragonet in the presence of a predaceous fish. To transfer either the one or the other to a strange tank is not a fair test, and this must be borne in mind in considering the conclusions to be drawn from the experiments which I have made.

On the north side of the aquarium is a very large tank, the further recesses of which are shrouded in obscurity. It is the dwelling-place of sundry conger, dog-fish, skate, wrasses, &c., and, in particular, of a number of large turbot, which last are in the enjoyment of excellent appetites. On several occasions during

the breeding-season of the Dragonets, I endeavoured, with the assistance of my friend Mr. F. Gover, to observe the behaviour of large males when dropped into the presence of the turbot. However, the former invariably managed to reach a dark corner before the turbot became aware of their presence, and we never saw them again. They may be there still, since there are many small fish, wrasses of several species, in the recesses of the tank, which do not show themselves at the front once in a month. On another occasion a similar experiment, with more fortunate result, was made by Mr. E. J. Allen, Director of the Laboratory, and myself. We succeeded in making a large male Dragonet, brilliantly coloured, swim over the part of the tank frequented by the turbot. One of the latter started in pursuit, and the Dragonet bolted at full speed, *with dorsal fins depressed*, but was caught and engulfed. No sort of effort was made to display the colours. Here the Dragonet was on strange ground and the turbot at home.

After pairing had ceased and the colours of the male Dragonets had greatly faded I placed a large turbot in their tank. As the big fish descended to the bottom the Dragonets, large and small, darted wildly away, and some buried themselves in the gravel. The turbot appeared only concerned to get out of the tank, which is much better lighted than the one in which it has spent the last few years. It paid no attention to the Dragonets, but kept swimming backwards and forwards along the bottom, generally close to the glass. Whenever it approached a large male Dragonet the latter would put up his dorsals and dart out of the way, not very rapidly. Once the turbot came to rest opposite a corner in which was a large male Dragonet, who erected his dorsal fins and slowly glided past the intruder. As long as the turbot was left in the tank the Dragonets seemed uneasy and kept moving about, but they did not display their fins unless the turbot was quite near them. One got out of harm's way by clinging to the side of the tank by the pelvic fins, which, as is well known, are capable of acting as a sucker (as in *Gobius*), though not very often used in this way. Here the Dragonets were at home, and were not actually attacked by the turbot, whose attention was distracted by his unwonted surroundings. I think it is clear that the male Dragonet does display his fins to intimidate a possible enemy, but it is impossible to say to what extent he relies on the efficacy of the exhibition should the enemy actually attack him. As a matter of fact, fully-developed male Dragonets are, under natural conditions, frequent victims to predaceous fishes; but this question may be discussed more conveniently at a later stage.

Small Dragonets, whether male or female, have also been observed to erect one or both dorsal fins at the approach of a large fish or a net, always provided that they have been in the tank for some time. While catching specimens in the various table-tanks in which they have been kept, I have often noticed that small Dragonets will hoist the first dorsal fin at the approach of the net; sometimes they remain still for a time, waving the

fin from side to side. In females and undifferentiated males the hind part of the fin is occupied by a dark marking which sometimes takes the form of an intense black spot extending over nearly half the fin. It is my impression that the individuals with the darkest fins are more prone to display than their paler brethren, but I should not like to insist on the correctness of this observation [1]. In table-tanks a momentary elevation of the pale second dorsal is difficult to detect. I therefore made (on the 11th April) some experiments in the deep aquarium tank with a view to more satisfactory observation of this point. A half-grown Tub Gurnard (*Trigla hirundo*) and an Angel (*Rhina squatina*) were successively introduced into the Dragonet tank. I was able to satisfy myself that on the near approach of either of these fish the young Dragonets sometimes elevated both dorsal fins. The elevation of the second was always of very short duration, and in some cases only partial. Some of the specimens seemed content to rely entirely on their resemblance to the gravel (as I have also noticed in catching them), and did not hoist their fins at all. One specimen, which made violent endeavours to leap out of the tank on the approach of the gurnard, was, and remained for some time, unusually pale after returning to the bottom. A similar change of colour was pointed out to me by Mr. F. W. Gamble in one of two young specimens taken from the table-tank on the same day. The emotion of terror appeared in both cases the most probable stimulus. As contrasted with the large differentiated males small Dragonets certainly display their fins, in the presence of danger, much less invariably. On one occasion, the intruder being a turbot, it was observed that a young Dragonet, near which the turbot had settled, erected the fore part of its body by a vertical depression of the pelvic fins and remained in this attitude until the turbot went away. The Dragonet was not on the gravel, but on a white ledge of the side of the tank. The attitude may possibly have been intended to enhance its apparent size, or may have been merely a preliminary to flight, if attacked. The dorsal fins were not erected.

It is noteworthy that large males, when threatened, do not assume the full courting attitude. The cheeks may be puffed out, but the jaws are never protracted to the full extent, and sometimes not at all. The preopercular tridents can be thrust out free of the sides of the head at will; but I have never seen this done in the water, unless the fish were actually seized. It will then strike with its head from side to side.

[1] Poulton ('Colours of Animals,' p. 166) has quoted a suggestion of Mr. Garstang's to the effect that the black first dorsal of the Weever (*Trachinus vipera*) may subserve the function of a warning signal. It has been suggested by Cunningham (Journ. M. B. A., n. s. vol. i., 1889, p. 37) that the Dragonets and Weevers are allied forms. Apart from the question of affinity, there is the obvious suggestion of mimicry, on the part of the non-poisonous Dragonet, of the really formidable Weever, but some further investigation of the habit and habitat of the two forms seems indispensable to a profitable discussion of this question.

Though differentiated males exhibit their dorsals, and especially the second, much more readily than other members of their species, they by no means neglect an opportunity to escape observation. Thus I have several times seen a male, approached by a dangerous intruder, remain quite still except for the movements of the eyes. If the enemy showed signs of approaching too near, the Dragonet would stir slightly and even commence to raise its fins, but these were at once dropped again when it appeared that the enemy was about to pass on. This happened after the breeding-season, when the male Dragonets were by no means conspicuous when at rest.

V. *Preliminary Discussion of the Colour-Mechanism and Differentiation of Coloration.*

It is known that in birds the sexual differences of coloration, though often very striking, are not due to the presence in one sex of any pigment that is not present in the other. The diverse effects result from differences in the texture of the feathers, involving diverse conditions of interruption of the pigment (*cf.* Beddard, 'Animal Coloration,' p. 4). As might be supposed, the same pigments are present in both sexes of *Callionymus*. They consist of a yellow, probably a lipochrome, and a black, which may be presumed to be melanin. The researches of various observers have shown that the elements which contribute to the coloration of the Teleostean skin are (i.) pigments, whether contained in chromatophores or partially diffused, (ii.) a reflecting substance, distributed in a variable manner and found to consist, in cases that have been investigated, either of guanin or "guanin-kalk," a combination of the former with lime. Isolated crystals of calcium phosphate have been detected in some forms, while hæmoglobin in the underlying muscles is an occasional contributor to the superficial coloration. It will be readily understood that variation in the distribution of yellow and black pigments alone may produce in different parts of the skin a range of coloration from pure yellow through brown to black, while manipulation by expansion or contraction of individual chromatophores may give rise to the well-known "protective" changes common to most of the bottom-living fishes[1]. Such changes occur in the female and young male of *Callionymus* and in the parts of the adult male which are not affected by the sexual differentiation, but need not concern us here. Both the pigments and the reflecting substances present in many fishes have received a certain amount of attention by various authors. The reflecting substance in *Alburnus* and *Argentina* has been shown to consist of guanin[2]. The brilliance of the iris in certain forms has been traced to the optical properties

[1] *Cf.* Agassiz, "Development of the Flounders," Proc. Amer. Acad. xiv. 1878, p. 14, pl. viii.; Cunningham, 'The Common Sole,' 1890, p. 110, pls. i.-iii.

[2] Barreswil, Compt. Rend. liii. 1861, p. 246. Voit, Zeitschr. wiss. Zool. xv. 1865.

of "guaninkalk,"[1] and the coloration elements of the skin have been investigated, in each case through a series of species of Teleosteans, by Ewald and Krukenberg[2], and by Cunningham and MacMunn[3].

So far as I am aware, the histological and physiological changes involved in the sexual colour-differentiation of fishes have received but little attention. In fact, I believe that Heincke[4], in his observations on *Gobius ruthensparri*, is the only contributor to this subject. In the goby some of the distinctions which Heincke supposed to be sexual have been shown by Guitel[5] to be in some degree common to both male and female, and, although the male is certainly the more brilliant and especially at the breeding-season, the differences of coloration, except such as affect some of the fins, are only those of degree. The sexual colour-differentiation of *Callionymus* is infinitely more striking, and since my observations bring out some points not touched upon by Heincke, it appears worth while to put them forward even in their present imperfect condition. I hope to find time to complete them, and to include in my inquiry such other sexually dimorphic forms as may be procurable.

Pouchet's term "iridocyte," applied to plate-like aggregations of the reflecting substance which show some traces of a cellular nature or origin, has been retained by Cunningham and MacMunn, who apply a new term, "argenteum," to a layer of particles of similar substance which usually constitutes the most deeply-seated element of the colour-mechanism.

The authors show that the reflecting substance of the outer layer is not always found in the form of definite plate-like bodies, but may be present in minute particles of variable shape, which apparently do not always differ from the particles composing the argenteum except in their topographical relations. It was found that the reflecting substance usually consisted of guanin, though calcium phosphate was present in some species.

I cannot at present deal with the chemical nature of the colour-elements in the Dragonet, and must therefore confine myself to a preliminary discussion of their disposition and sexual and developmental differentiation.

Since the young male and the female are identical in coloration, it is only necessary to compare the several colour-phases of the former sex. The Dragonet is said to have no scales, and a minute histological examination of the skin shows no obvious trace of such structures. It is most abundantly supplied with mucus, which it throws off in slimy clouds when irritated. The secretion

[1] Kühne u. Sewall, Untersuch. Phys. Inst. Heidelb. iii. p. 221.

[2] Zeitschr. f. Biol. xix. 1883.

[3] Phil. Trans. R. S. clxxxiv. 1894, p. 765. I am indebted to these authors for most of the above and for other references.

[4] Schr. Naturw. Ver. Schlesw. Holst. 1875, i. p. 290. A full translation is given by Smitt, Hist. Scand. Fish. ed. 2, i. p. 242.

[5] Arch. Zool. Expér. sér. 3, iii. 1896, p. 264.

is as abundant in young examples as in old. I have found neither chromatophores nor reflecting substance in the epidermis. The numerous large epidermal alveoli of the mucous system need not here concern us, since, though apparently acting to some extent as condensers, they do not alter the effect of the underlying coloration-elements and are alike in both sexes.

The second dorsal fin is one of the parts most conspicuously coloured in the mature male. In the young undifferentiated male the markings are sombre. If a young specimen be compared with the drawing (Plate XXVI.), it will be seen that the yellow area (of the adult) is brown, the blue lines are opaque white, and their grey margins are colourless and transparent. Sections of this fin show that the skin consists, internally to the epidermis, of loose connective-tissue cells overlying a thin fibrous layer, apparently representing the chorion. Except where the rays intervene, this layer is closely apposed to the corresponding element of the skin of the other side. The chromatophores lie in the loose connective tissue already mentioned.

In the young male the brown bands are found by microscopic examination to derive their colour from very numerous yellow and black chromatophores. In connection with the latter are frequently seen underlying masses of finely granular matter, of a brownish colour by transmitted light. As the chromatophores contract it becomes evident that there is a large quantity of apparently similar matter arranged in a continuous network resembling strands of dendritic chromatophores. By reflected lig t this network takes on a pale yellow colour. It has hardly any iridescence.

Passing towards the transparent areas which border the white bands, one observes scattered chromatophore-like aggregations of the same substance, some of which contain a little black pigment, while intermediate conditions lead up to perfect black chromatophores. It appears, therefore, that these bodies are merely degenerate black chromatophores. The transparent areas are simply devoid, or nearly so, of any sort of coloration-element. The white bands have a few black chromatophores, but the degenerate structures are much more numerous. The opaque white appearance is derived from a granular reflecting matter, arranged in an irregular network, appearing steel-grey in colour by reflected light over a black surface. So far as I can see, it has no connection with the chromatophores, though it may be of the same chemical nature as the granular matter associated with the latter.

In the adult breeding male the brown bands are brilliant yellow. This result appears to have been achieved (i.) by the reduction of black chromatophores, which are now much less numerous than in the undifferentiated stage and sometimes entirely absent, (ii.) by the excessive development of yellow pigment.

In the fresh condition the ground-colour of the yellow bands is a diffuse yellow; no separate yellow chromatophores can be discerned until the diffuse stain has been extracted by a reagent.

They are then seen to be stellate in character, but much smaller than the black ones. Cunningham and MacMunn, who record an approach to this condition of diffusion (*op. cit.* p. 776), provisionally suggest that the coloured pigment in the flounder and plaice diffuses from the connective-tissue cells in which it is deposited [1].

In the case of *Callionymus*, comparing the young and adult conditions, no other conclusion seems possible. A complete network of granular matter certainly represents the black chromatophores present in the younger stages.

The white bands and their transparent margins have become blue, with a border of grey, but only black chromatophores are present. The latter are abundant in the grey area, and are here of a dendritic nature. In the blue part I find them less numerous and, in microscopic preparations, much less expanded, the radii being very short and the centre very dense. In both cases they are frequently, if not always, associated with underlying masses of a granular matter. The brilliant blue colour is derived from a dense network of bundles of small, somewhat bean-shaped bodies. The latter are yellow by transmitted light, but intensely blue by reflected light over a black ground, such as is afforded by a black chromatophore. They occur immediately below the epidermis. It is difficult to isolate them, as in the process of teasing out they are readily ruptured and resolve themselves into minute rod-like crystals. They appear to correspond to the iridocytes of Pouchet and of Cunningham and MacMunn, but are very minute, and are certainly not associated with the chromatophores in the same manner as is described by the last-named authors in the case of the flounder. I have not been able to detect a circular aperture, and have entirely failed to obtain sections. It will be perhaps more convenient to term them, provisionally, "*prismatic bodies*" instead of iridocytes.

They may probably prove to be identical with some reflecting substance found in small quantities by Cunningham and MacMunn (*op. cit.* p. 773), in *Siphonostoma*, but not, apparently, in other forms examined by those observers. They appear to be represented in *Gobius*, a form closely allied to *Callionymus*, and are there termed by Heincke "chromatophores filled with small discs of a metallic lustre." These "chromatophores" were supposed to contain pigment, but Heincke, who examined them only in the living fish, acknowledges that the pigment may have been really external. I find that the blue colour of the dorsal fin in the male *G. minutus* is identical in mechanism with that of *Callionymus*.

We have seen that these bodies are yellow by transmitted light. The rod-like particles into which they may be broken up are also yellow, but, though highly iridescent by reflected light, their iridescence is usually yellow, sometimes green, and only rarely

[1] The yellow pigment of *Carassius* was usually met with by the same observers in diffuse condition.

blue. It is therefore evident that the prismatic body owes its property of cerulescence to the manner in which its component parts are arranged. Owing to the minute size of the whole body, I have not been able to ascertain its internal structure. The bundles of prismatic bodies (fig. 1 *a*, p. 289) [1] are arranged in a direction roughly parallel to the axis of the fin-ray, the individual bodies transversely. Typically they seem to be arranged in a single layer, but often they overlap one another. The whole network lies in a slightly higher plane than the chromatophores, or at least passes over them when they are encountered in the same vertical plane. Sections of the fin are possible only when the bodies have been entirely removed by the action of acids, and I cannot find any trace of their associations with the connective tissue. Presumably they occupy the interstices of the latter, as suggested, for the iridocytes, by Cunningham and MacMunn. Their component rod-like particles may be simply deposited in a regular relation in such interstices, or may be held together by some matrix. None of these bodies occur in the grey margin of the blue band, where the colour-elements differ only from the young condition in the much greater abundance of black chromatophores.

In a male examined shortly after the breeding-season the yellow of the body has faded to a golden brown, while that of the fins is paler than at the time when pairing was in full progress. Examination of the yellow bands shows that the diffuse pigment is reduced in quantity. In the blue part are noticed aggregations of brownish granular matter, superficial to the prismatic bodies, sometimes alone, often in relation to a black chromatophore. I believe that they are derived from the degeneration of the black chromatophores, as in the case of apparently similar matter in the yellow bands. A reduction of the black chromatophores of the blue band would of course result in a diminution of the blue colour, since the prismatic bodies are blue only when backed by black.

It will be noticed that in the drawing (Plate XXVI.) the bands of the first dorsal fin are white with grey margins. This is the usual condition, but occasionally they have a certain blue tinge, especially near the base of the fin. The white appearance is derived from a network of reflecting matter, very similar to that of the blue of the second dorsal, but the individual prismatic bodies are considerably smaller, and there are very few black chromatophores in this region. In several specimens I find that the latter are superficial to the reflecting tissue. In an example in which the bands of this fin are distinctly though not very brilliantly blue, I find the prismatic bodies as large and as numerous as in the second dorsal. Black chromatophores are somewhat less abundant than in the other fin, but have the same relation to the reflecting matter, which is fully cerulescent over a black surface. The deficiency of colour is thus

[1] Fig. 1 *a* is only a sketch. The minute size of the bodies renders the use of the camera lucida impossible in their individual delineation.

evidently due to the comparative scarcity of black pigment. I have never seen the red tinge shown in Smitt's figure (Hist. Scand. Fish. ed. 2, pl. xiv.), but it is a fact that prismatic bodies, when seen by transmitted light in dense masses, tend to exchange the ordinary pale yellow for a warmer tint. In the hinder part of the blue margin of the axillary ocellus is an intensely brilliant region. Here it will be found that some of the prismatic bodies have a crimson colour in perfectly fresh preparations. Individually they are violet by reflected light over a black surface. The action of glycerine rapidly reduces them to the usual pale yellow tint, and I cannot say by what cause the crimson colour is produced.

With regard to the coloration of the body, the differentiation is achieved in a manner parallel to that which obtains in the dorsal fins. We need therefore only discuss the colour-mechanism of the adult male. The skin of the body differs from that which constitutes the fin-membrane in that the chorion is thick and tough and is associated internally with a further layer of loose connective tissue. In *Callionymus*, as was noted in the case of other Teleosteans by Cunningham and MacMunn, this inner layer frequently adheres to the muscles when the skin is stripped off. The epidermis, especially in mercuric chloride or old alcohol preparations, can readily be isolated. It contains neither chromatophores nor reflective tissue in any part which I have examined. In the blue bands of the side externally to the chorion are found black chromatophores in variable number, but often abundant. In the same plane and to some extent superficial to these occurs a diffuse layer of prismatic bodies, similar to those of the second dorsal, but showing less tendency to a retiform arrangement, owing to the closer approximation of the bundles. The internal layer of connective tissue is very rich in strands of prismatic bodies, overlying and passing between numerous black chromatophores. In preparations I find many of the latter completely contracted. It has been noted that these bands are subject to momentary intensification of colour, and it may reasonably be supposed that such intensification is effected by expansion of the chromatophores in response to nerve stimuli, causing a greater surface of black pigment to be interrupted by the overlying prismatic bodies. On the pelvic fin (*cf.* Plate XXVI.) are certain streaks of blue, which, during the breeding-season, remain of a constant deep hue. Here it is found that prismatic bodies overlie layers of black chromatophores so closely set as to present a practically continuous surface, a condition which sufficiently explains the constant character of the colour [1].

[1] Heincke found that (as I can confirm) in *Gobius ruthensparri* the metallic lustre is brought about by the crowding together of the "chromatophores" containing the glittering substance. *Callionymus* is too large to be conveniently studied under the microscope in life. Although the bundles of prismatic bodies show a *post-mortem* tendency to contract, it appears to me that the background is more influential in colour-production than the arrangement of the bodies.

Underlying the chromatophores of the inner layer of the skin in the blue bands (and elsewhere) are nests or aggregations of reflecting tissue in minute particles. Such are everywhere present in similar association with the black chromatophores in both sexes. When the chromatophore is fully expanded its central part is transparent and practically colourless, and the underlying nests can be seen from the outer side. In such aspects they are not refractive, but, if the preparation be reversed, they are found to have in part optical properties similar to those of the prismatic bodies. Particles of a nest will be found to glitter with the same blue colour, but in parts of the skin where yellow pigment occurs the latter affects them very strongly, causing the refraction to be chiefly yellow, sometimes green (from the mixed influence of yellow and black pigment?). In a nest underlying a black chromatophore remote from yellow pigment the bulk of the reflecting matter, viewed from the inner surface, is steel-grey in colour, portions, as already noted, being blue.

Reflecting matter of a similar nature forms a more or less continuous "argenteum" under the coloured parts, the minute elements being often, if not always, rod-like in shape. The skin of a young male, in which no prismatic bodies have been developed, can be cut with the microtome without the necessity of entirely dissolving out the reflecting tissue. Here the black chromatophores of the innermost series are seen in section, sometimes imbedded in a thickened depression of a continuous argenteum, sometimes overlying masses of similar tissue detached from each other.

The skin of the white ventral surface of the abdomen in old or young has a dense white argenteum and no chromatophores. The argenteum may be resolved into minute rod-like particles, similar to those obtained by rupturing the prismatic bodies of other parts, and to those which form the much thinner argenteum of the sides. The white effect appears to be due to the manner of their arrangement, since, if traced out, the elements of all reflecting tissue whatsoever seem to possess the same optical properties [1].

The masses of reflecting tissue underlying the black chromatophores (equally present in both sexes and at all sizes) can certainly play no part in the colour-mechanism of the body, since they are only refractive from the internal aspect. In the transparent fin-membranes they may feebly contribute to the coloration. Cunningham and MacMunn, who have noted that the iridocytes of the Flounder are closely embraced on the outer side by the black chromatophores, offer no suggestion as to the function of the former. It is difficult to see that they have any influence at all, in such association, on the colour-effect.

The results obtained by the various observers who have investi-

[1] For the present I do not include as reflecting tissue the brown granular matter, which I have shown to be probably a derivative of degenerate black chromatophores.

gated the colour-elements of the Teleostean skin suggest that guanin is probably the most important component of the reflecting tissue in *Callionymus*. My friend Mr. G. Brebner has detected its presence, and tells me that calcium is abundantly present in all parts examined, including the loose inner layer containing the argenteum. This was also the case in the reptiles, &c., examined by Ewald and Krukenberg[1]. I have not found in *Callionymus* any large crystals of calcium phosphate, such as occur in the skins of some fishes. Judging from its optical effect, I do not suppose that the reflecting substance differs in chemical composition in different parts of the skin or in individuals of different ages. Apart from the yellow pigment I provisionally suggest that the colour-change is caused (i.) by the excessive development in the adult male of a reflecting substance (probably guanin) common to both sexes and all stages, and by the definite disposition of its particles in composite structures—the prismatic bodies; (ii.) by the distribution of black chromatophores in relation to the said prismatic bodies.

Agassiz and Ewald and Krukenberg refer to a paper by Brücke (Sitz. Wien. Akad., math.-nat. Classe, Jahrg. 1851), which I have not been able to consult. It appears that the author has dealt with the mechanism of the well-known colour-changes in the Chameleon, and demonstrated the property of cerulescence under certain conditions of the reflecting elements, which Ewald and Krukenberg subsequently found to be composed of guanin. We have seen that in *Callionymus* the property of cerulescence is confined to the prismatic bodies (if we except the occasional manifestation of the same property by particles of the masses of reflecting tissue which underlie black chromatophores), and that these bodies are found in association with black pigment only. With a view of testing the effect of the yellow pigment, I have isolated pieces of the blue skin from one side of the dorsal fin and compared the colour-effect of the prismatic bodies (i.) when the skin is viewed alone, in its natural association with only black chromatophores, (ii.) when the same skin is stretched over a bit of the yellow part of the same fin. It is at once apparent that the underlying yellow pigment changes the effect of the bodies as seen by reflected light. Instead of sapphire-blue, the resulting colour is a rich metallic green in general effect: though many individual prismatic bodies show various other tints; some, which, it may be presumed, happen to interrupt the view of yellow pigment only, being a pure yellow. It is evident that if, under natural conditions, the prismatic bodies were associated with both black and yellow pigment, manipulation of the latter would achieve a very considerable range of coloration.

[1] Untersuch. Physiol. Inst. Heidelb. iv. 1882, Heft 3.

VI. *The Soluble Pigment and the Palatability.*

The yellow colouring-matter, already noticed as diffusely present in the yellow bands of the fully-differentiated and breeding male, is very readily soluble soon after death. Francis ('Nature,' xiii. 1875, p. 167) has recorded the existence of a bluish-green pigment in the Australian Wrasses *Odax* and *Labrichthys*, which is soluble (presumably after death) in (fresh) water and sea-water. It is nitrogenous and is destroyed by heat, chlorine, acetic acid, alkalies, ammonia, and alcohol; precipitated but not destroyed by sulphuric acid; bleached by light. The yellow pigments of various fishes studied by Cunningham and MacMunn appear to have been less soluble, and these authors note that Francis's observations have not been confirmed. A bluish-green colouring-matter is certainly freely extracted from many European Wrasses in weak formaldehyde, but I have never tested its solubility in water alone. In *Callionymus* the yellow pigment is not given off in perceptible quantity during life, but very soon after death it readily dissolves out in fresh water, sea-water, dilute formaldehyde, glycerine, or alcohol without change of colour. Ether extracts an ochre-coloured solution; mercuric chloride changes the yellow parts to brick-red and extracts a solution of similar colour. Chloroform extracts no colour. A strong aqueous solution is not affected by heat nor by alcohol, is intensified by the addition of ammonia, becomes colourless with acetic acid, and much more rapidly with hydrochloric acid. The colour bleaches very rapidly in light.

The female has no yellow markings and no diffuse pigment, but a similar yellow colouring-matter is extracted in small quantity by alcohol from the chromatophores. Water appears to immediately extract only the diffuse pigment, and therefore has no effect on the female or young male.

A strong aqueous solution of the yellow from males has an odour resembling that of an acrid cucumber. The same smell is perceptible in the fish as a whole, and, to some extent, in both sexes. The solution has a subacid taste, not particularly disagreeable, but causes a prolonged irritation of the salivary glands. The same results are experienced if one chews a bit of the second dorsal fin of the male. The mucus can be easily obtained by irritating the fish. It is tasteless and non-irritant, so that the offensive properties clearly belong to the colouring-matter [1]. It has been shown that the yellow pigment is most abundantly present at the commencement of the breeding-season and subsequently fades to a great extent. The manner of its disappearance requires explanation. Considering the nature of pigments generally, it seems improbable that the yellow matter is re-absorbed by the blood-

[1] I have not fully investigated the epidermal glands. It is possible that some of these may secrete the irritant fluid. If so, it accompanies the diffusion of the yellow pigment; but as the structure of the epidermis seems constant and no irritant matter is discharged by young examples, it is much more probable that the diffused yellow pigment is actually the seat of the irritation.

vessels. Is it simply diffused off into the water, or does it bleach *in situ* and so cease to be conspicuous? The former supposition seems to be the more probable, though it is not possible to see any trace of it. At present I have no means of applying any test other than that of vision, from a want of knowledge of its chemical nature. The researches of Gowland Hopkins[1] in Butterflies suggested to me that uric acid or urea would very probably be found in the yellow pigment. With the assistance of my friend Mr. F. Bishop Harman, M.B., I made several tests, but the results were negative. However, the fact remains that the pigment, whatever its exact chemical nature, is, presumably, an excretory product and has certain properties of taste and smell. It is found only in the skin, and differs entirely in that respect from the biliary colouring-matter which I have occasionally found infecting all parts of a Teleostean.

In considering the function of the pigment, it is necessary to note that it is exhibited, by the erection of the dorsal fins, not only in courting the female and in frightening smaller members of its own sex, but also in the attempt, successful or otherwise, to intimidate predaceous fishes. Since the pigment is certainly most abundant at the breeding-season, it may be presumed that it is primarily sexual in function. In this connection it is not easy to decide whether it appeals only to the visual faculties of the female or to her sense of smell as well. The impression I have gathered from repeatedly watching the Dragonets in the aquarium tank and in a large table-tank in the main laboratory is that these fish, in which the olfactory organ is very small, depend almost entirely upon their eyesight in feeding. I have often seen them take into their mouths quite uneatable substances which bore a casual resemblance to the worms which form their usual food. To further test the matter I made a decoction of *Nereis diversicolor*, the worm in common use here, by pounding up a number of specimens in a little sea-water. The fluid poured off must have been, to the olfactory sense of a fish, identical with the actual worm; but the Dragonets in the table-tank took no notice of it whatever. A prawn evidently perceived it, and began to hunt about where some of the suspended particles had fallen. A portion of the same fluid dropped into one of the large aquarium tanks had the effect of rousing a shoal of grey mullet and some red mullet, previously quiescent, to great activity in search of food. It is evident, therefore, that *Callionymus* is not keen of scent, since a few worms dropped in their tank suffice to bring them from all parts to share the feast. I have not devised any means of testing the effect of smell on the sexual passions of the fish as apart from its appetite, but I can affirm that the yellow pigment is neither distasteful nor terrifying to young members of the species. I made an aqueous solution of the yellow from the dorsal fins of a mature male and soaked in it small balls of cotton-wool, which

[1] Proc. R. S. lvii. 1894, p. 5, &c.

were dropped into the large table-tank. Several wrasse, *Labrus* and *Crenilabrus*, darted at these objects, but either retreated without touching them or dropped them as soon as they were seized, and departed in evident disgust. Gobies, chiefly *G. paganellus*, investigated the matter and seized the coloured balls, but mostly dropped them very shortly. One carried off a ball to a shelter in the middle of the tank, but then dropped it. Only one goby made any attempt to masticate a ball, and that was soon abandoned. The young *Callionymi*, on the contrary, took the balls greedily and chewed them. The same fish would take a ball, chew it for some time, reject it and seize it once more. Certainly the yellow matter was not distasteful, nor was the colour terrifying. Fragments of the second dorsal were treated in the same way as the balls by wrasse and gobies, but greedily attacked by young *Callionymi*; the fin-membrane was swallowed, when separated by repeated chewing from the rays. A quantity of the solution was poured over the assembled *Callionymi*, who took no apparent notice of it. A wrasse saw the yellow colour and darted out of its hiding-place, but rapidly retreated on reaching the foreign matter. It seems, therefore, that terror is inspired in young Dragonets by the menacing gestures of the courting male, and not by the optical or olfactory properties of the yellow pigment. Of course I am not contending that the yellow colour is actually attractive to young Dragonets, since most of the fish, of whatever species, in the table-tank are so far tame that they will come and look at anything that is offered to them. It appears to me impossible to decide in what manner the elements of the coloration of the male influence the female. If it appeals to her sense of scent, the yellow element only can be concerned, since the blue results from a combination of two elements which are not soluble. It certainly appears most probable that the whole coloration-effect merely renders the large dorsal fins more conspicuous and so advertises the whereabouts of the male. As we have seen, the dull-coloured female does not appear to be readily perceived by the male even at the distance of a few yards. Her presence may presumably be indicated by some odoriferous product of the genital organs at the season of ripeness.

Apart from the sexual question, we have seen that the yellow colouring-matter is distasteful to gobies and wrasse. The latter, however, are not to my knowledge fish-eaters. Gobies are more or less indiscriminate in their appetite. Except dog-fish, rays, and conger, which seldom feed in the daytime, the only large fish-eating forms in the aquarium are pollack and turbot. Both these species must be present on the *Callionymus* ground during the breeding-season. The pollack feeds very largely on fish. Those in our tanks appear hardly large enough to take a full-grown Dragonet, so my experiments have been made with pieces cut from the sides of large males in various stages of colour, large females treated in the same way, and small living undifferentiated specimens. The larger pollack often took the bits of Dragonet,

but always rejected them. Bits of male and female, *with or without the skin*, appeared to be equally distasteful. A smaller pollack, present in the same tank, once took and retained a piece, probably because its opportunities of feeding are so limited by the competition of the larger fish that it cannot afford to be discriminating. These experiments were checked by offering bits of *Gobius paganellus* at the same time. The goby appeared much more palatable, most of the bits being taken and retained. A number of small living Dragonets were dropped into the same tank. Some reached the bottom in safety. Four were caught by the pollack, which swallowed two outright, one having had the preopercular spines removed. Another, with spines intact, was seized and held for so long that, even if not finally swallowed, it certainly could not have been violently distasteful to its captor. Another was seized by the tail and struck the pollack's lip or cheek with its spine and was instantly dropped. It was captured by another pollack and, I think, swallowed.

Some small Dragonets were offered to a number of pollack, about a year old and about 6 to 8 inches long. Most of them escaped into crevices of the rockwork or reached the bottom. One was seized and rejected, but perhaps swallowed by another fish in a dark corner of the tank. Another was seized and rejected, with evident manifestations of disgust, by five pollack in succession. The first four got it by the head and probably pricked their mouths, but the last seized it by the tail and seemed equally disgusted. Another, offered immediately afterwards, was smelt by most of the pollack, but taken by none. No dead individuals were taken, neither was a dead *Gobius minutus*, though this species is relished when living. The above evidence is rather conflicting. The larger pollack certainly appear to dislike bits of large Dragonets, but the seat of distastefulness is not entirely in the skin. The same pollack appear, on the whole, to approve of small Dragonets, while the latter seem to be distasteful to small pollack.

Pieces of large Dragonet were taken greedily and eaten by *Gadus luscus* and *G. minutus* and by *Cottus bubalis*. The last-named fish, however, will eat most things. Bass (*Morone labrax*) will not touch *Callionymus*. They are not fish-feeders. Wrasse (*Labrus maculatus* and *L. mixtus*) either decline to touch or at once reject bits of large *Callionymus*. As we have seen, young wrasse appear to dislike the pigment.

Turbot seem to find nothing objectionable in *Callionymus*. Small turbot and brill inhabit the bottom of the tank in which are the larger pollack. In the course of the experiments just described I noticed that the rejected morsels and such young Dragonet as reached the bottom were eagerly swallowed by the turbot (and, I think, brill also) as soon as they came within their sphere of influence. Some experiments with large turbot in the next tank have already been described. In addition I have on several occasions offered these turbot a number of dead male Dragonets

in full colour. The preopercular spines were removed from some, left intact in others, but the turbot swallowed all alike, the same fish taking several in rapid succession. The Dragonets being dead, the yellow pigment was in a highly soluble condition, and its properties of smell and taste must have been perceptible. Turbot hunt chiefly by eye, and those in the tanks will often take swimming crabs, but soon reject them. I have also seen them take "hard-heads" (*Agonus cataphractus*) and immediately spit them out again. In both cases I imagine that the armour of the intended prey was found to be compensated by no delicacy of taste. The Dragonets were often held in the mouth for some time until shifted into a position convenient for swallowing. I have never seen one even temporarily rejected.

As described above (p. 295), a living male Dragonet was taken by a turbot. Its subsequent proceedings appear worthy of record. The Dragonet, though successfully engulfed, appeared to be struggling and had almost certainly erected its preopercular tridents. The turbot seemed in great difficulties, making violent movements with its jaws and apparently unable to close its gill-apparatus, through which the dorsal filament of its victim occasionally protruded. Its efforts, however, appeared to be directed to swallowing, and were quite different to those which occur when the fish is trying to get rid of a swimming crab. After some time the turbot retired to a dim corner of the tank, and remained for several minutes quiet, but with gill-cover slightly distended. It then returned to the front of the tank, apparently all right. I tempted it with several dead *Callionymi*. It took no notice of the first five of these, which were taken by other turbot. As the sixth neared the bottom our friend made an advance towards it, but did not take it, and it lay on the bottom a little way off. The wave of a passing fish stirred it a little, and another slight advance was made, but without further result. Then commenced a series of violent convulsive twitchings of the abdomen, affecting the part lying behind a line from the anus to the extremity of the pectoral fin. They may have been caused by irritation from the spines of the victim, or may, more probably, be explained as an effort to pack it in a more convenient position. The twitchings lasted perhaps a minute or two. Then the fish circled round the end of the tank and returned to the same spot. A few more twitchings and matters seemed to be satisfactorily settled.

The turbot again made a circular tour, and, returning, appeared to perceive the dead *Callionymus*, now lying in a natural position, and swam at it as if about to take it, but stopped short and took the ground within an inch. Then commenced a rapid downward flipping of the fore part of the dorsal fin. The nostril underlies this region, and it was evident that the turbot was smelling at the *Callionymus*. The result was, apparently, not immediately inviting, but soon afterwards, having once more swum round the clear part of the tank, the turbot, in the act of settling, did finally

take the *Callionymus*—also some gravel. The latter was soon ejected, and the Dragonet swallowed without any difficulty.

According to my experience turbot, under natural conditions, feed entirely on fish, chiefly Clupeoids and sand-eels, and Cephalopods. In the tanks they are attracted by moving objects, and do not (except in the above instance) pause to smell their food. The experiments which I have described seem to show that the adult male *Callionymus* enjoys no immunity on account of the offensive properties, whether of taste or smell, of his person in so far as the turbot is concerned.

In the aquarium the yellow of the fins of some of the large male Dragonets had faded by the first week in April to a dull ochreous brown, the brilliant yellow of the body having disappeared long before. Nevertheless these fish still erected their fins on being menaced with a net quite as freely as during the season of brilliance, but required great provocation to induce intensification of the blue bands. This suggests that although the elements of the blue coloration are in great part retained after the breeding-season, the willingness to utilize them diminishes.

Under natural conditions the Dragonet is a frequent victim to the cod (M'Intosh); I have myself recorded it from the stomachs of this fish and of the turbot and *Raia fullonica*. My colleague Mr. Garstang has found it (as noted by Poulton, *loc. cit.* p. 166) in the stomachs of red gurnards (*Trigla pini*). In this last case the victims were small individuals only. The long rough dab (*Pleuronectes platessoides*) also takes Dragonets (Ramsay Smith). During the breeding-season of this year I have often seen full-grown males among the refuse on the Plymouth quay from the stomachs of fish, chiefly anglers, and, I think, ling. In all probability the large tub-gurnards (*T. hirundo*) which abound on the breeding-grounds at this season, and are to some extent fish-feeders, may be also reckoned among the enemies of the Dragonet. I cannot speak from personal observation as to the feeding-habits of the red gurnard. The grey gurnard (*T. gurnardus*) makes great use of its sensory pectoral rays in searching for food [1], and protective coloration would not be an efficient defence against a fish of such a feeding-habit.

Tub-gurnard hunt both by sight and touch, but in experiments which I made I could get no evidence as to the palatability of *Callionymus*, since on that occasion our aquarium specimens would not even interest themselves in worms, usually a favourite food. Cod hunt by sight (Bateson, *loc. cit.* p. 241), but a blind cod, as I have had the opportunity of observing, can detect the presence of food dropped into the tank and find it on the bottom. Indeed this fish must be largely dependent on senses other than that of sight at the great depths (over 100 fathoms) in which it commonly occurs in northern latitudes [2]. It is an indiscriminate

[1] *Cf.* Bateson (Journ. M. B. A., n. s., i. p. 248), whose remarks appear to deal with *T. pini* and another species.

[2] *Cf.* Holt and Calderwood, Sc. Trans. R. Dub. Soc. ser. 2, v. 1895, p. 429.

feeder, taking even such unpalatable organisms as *Alcyonium* and *Actiniæ* [1], so that it is not surprising to find that the various protective devices of *Callionymus* are frequently inefficacious. Whether or not the dorsal filament of *Lophius* is attractive to *Callionymus* I cannot say, but the male Dragonet, when courting, rushes heedlessly against anything that may be in the way, even against fully-expanded anemones, *Adamsia rondeletii*. *Lophius* appears to snap at precisely the spot where anything touches the erect filament [2], and, as a matter of fact, the Dragonets among the stomach-refuse on the fish-quay are mostly large males. Judging from the very varied assortment of things that have been found in the stomachs of *Lophius*, it may be presumed that its sense of taste is not very discriminating. I have not found Dragonets in the stomachs of John Dories (*Zeus faber*), but have seen a small specimen of the former taken and instantly rejected by a young dory. This fish does not appear willing to take anything from the bottom, though it will sometimes do so.

It is possible that prawns (*Palæmon serratus*) find something distasteful in the skin of a large male Dragonet. On two occasions I have noticed that a dead specimen placed in the table-tank was unmolested, though the prawns in the same tank will seize small individuals even before they are dead. A large male, which died in the aquarium tank during the breeding-season, was not injured by the crabs (*Cancer* and *Carcinus*) and hermits (*Eupagurus bernhardus*) for some time. The viscera and part of the muscles of a mature female were eaten, while her skin remained practically untouched; but I have seen a fully-coloured male chased by a *Carcinus*.

If the yellow pigment of the male is really obnoxious to any predaceous fish, it is evident that the female must also profit thereby at the moment when she is most exposed to danger, viz. when preoccupied in the matrimonial ascent.

VII. *General Considerations.*

The observations which I have collected above are certainly not so complete as they might be, but I do not think that further investigations will reveal many new facts in such part of the bionomics of the Dragonet as are intimately connected with the interpretation of the sexual dimorphism. Further study of the palatability of this fish, from the point of taste of the predaceous forms which it runs the risk of encountering under natural conditions, is certainly desirable, and will be carried out whenever opportunity permits.

In the meanwhile we know that the Dragonet is a species in which the male assumes, at a period roughly corresponding to the inception of sexual maturity, a differentiation of structure which

[1] Thomas Edward, 'Naturalist,' 1855.
[2] *Cf.* Holt, Sci. Proc. R. D. S., n. s., vii. 1892, p. 456.

distinguishes him at the first glance from his mate; that this structural differentiation is accompanied by the development on certain parts of a very conspicuous coloration, wholly absent from the female; and that the yellow element of this coloration has a distinct association with the ripeness of the genital product, rapidly fading after the early part of the breeding-season. We have seen that the yellow colour is that of a highly soluble pigment, characterized by a peculiar taste and smell, and distinctly irritant. The same pigment is present, in much smaller quantity, in the female; and the flesh, as well as the skin, of large examples of either sex appears to be unpalatable to at least one predaceous fish, the pollack, while even fully-coloured males are greedily eaten by the turbot. Male, female, and young alike possess a powerful preopercular spine, and are further protected by a copious mucous secretion. The male displays his secondary characters alike, whether in courtship (including the intimidation of younger members of his own sex), in competition for food with his own species, or in the apparent endeavour to prevent the attack of a predaceous enemy, though it is only in courtship that the jaws and teeth are fully exposed. We have no evidence of serious combat among mature males [1].

It remains to endeavour to fix the right interpretation of these various phenomena of form and habit. The coloration of the male sufficiently conforms to Poulton's definition of the epigamic character [2], in that the most conspicuous parts, at all events, are concealed when the animal is at rest. In the light of the pairing habit, unique, so far as I know, among fishes propagating by pelagic eggs, and of the readiness with which the blue colour is intensified during courtship, it is hard to regard the secondary structure and colour-characters otherwise than as due to some form of sexual selection. It matters little whether the excessive production of yellow pigment at the breeding-season has been evolved by sexual selection or whether it be an adventitious excretory process connected with genital activity. The possibility of the female being degenerate suggests itself, but is hardly supported by any evidence in the ontogeny. Perhaps in *C. lyra* the female presents a greater contrast to the male than in some other species of the genus; but, even if there were degeneracy in this sex, it might be regarded as a degeneracy from a condition originally acquired in response to the sexually-selected charms of the male.

I think it must be conceded that the account which I have given of the behaviour of the female at the time of pairing does not strongly support the view of an *æsthetic* sexual selection. In the dim light of 20 to 30 fathoms minute excellencies of design and colour-harmony must be hard to detect. Our female

[1] *Cf.* the perfectly harmless battles of courting spiders (Peckham, Occas. Papers, Nat. Hist. Soc. Wiscons., i. 1889, quoted by Poulton, 'Colours of Animals,' p. 310).

[2] *Op. cit.* p. 311.

appeared to exercise no choice at all, but simply took the nearest individual which offered the outward appearance of an able and willing male. I should hesitate to believe that the enlarged dorsals and brilliant colours of the male are other than a conspicuous advertisement of his whereabouts. It is practically certain that even in the small space of an aquarium tank the male cannot see the female unless she is quite close to him, and it is difficult to see why the converse should not hold good, were both sexes equally inconspicuous. It is true that when the male has found the female he continues to display his braveries, but in the absence of any evidence of individual preference on her part the æsthetic effect is at least doubtful.

In a much less degree the males of the allied genus *Gobius* and of *Blennius* and *Clinus* are distinguished by structure and coloration from the females. The admirably careful observations of Guitel [1] on the reproductive habits of these fishes give no indication of a sexual selection on the part of the female.

Males of *Clinus* and *Gobius minutus* were observed to fight for the possession of the female. Here the battles were of a serious nature and were decided by force of arms, the females being left to the victors. In *G. ruthensparri* the rivalry of the competing males was not carried beyond the stage of menace, and the result does not appear. In the other goby and in all the blennies serious combats ensue if the possession of the nest is disputed. Gobies and blennies appear to be polygamists, and if the females are more numerous than the males, the selective proclivities of the former are likely to be even less marked than in *Callionymus*, where the males preponderate.

It was observed by Savile Kent [2] that a male of *Gobius niger*, on being disturbed, distended its gill-covers and branchiostegal membranes, "with the evident intention of passing itself off as one of those spiny-headed Cottidæ which are not to be handled with impunity." *If* the inference is correct, this observation is probably important as bearing on the behaviour of *Callionymus*, since we are led to suppose by the context that the male in question was guarding its ova. In the forms studied by Guitel the same demonstrations of form and colour were made by the males whether in courting or quarrelling for possession of a mate, or in guarding the nest. It is possible that *G. niger* does actually mimic *Cottus*. It is perhaps equally possible that the unarmed gobies may be descended from spiny-headed progenitors, and may have retained the habit of protruding the once armed parts in courtship and defence of the young, if not also for ordinary purposes of self-defence. In *Callionymus*, as we have seen, certain demonstrations on the approach of danger are to some extent common to all stages of growth and to both sexes. I cannot find any important evidence that these phenomena are primarily or finally mimetic of anything

[1] Arch. Zool. Expér.: *G. minutus*, sér. 2, x. 1892; *Clinus* and *Blennius*, sér. 3, i. 1893; *G. ruthensparri*, sér. 3, iii. 1895.

[2] *Op. cit.* p. 242.

in particular[1]. The preopercular spines being reserved as a second line of defence, in case the animal be actually seized, it appears to me that the object is either to simply disconcert the enemy by a rapid change of form, or to convey an exaggerated impression of size and strength. It is on some such line that one may suppose that a finally mimetic condition (as instanced in the Puss-moth caterpillar[2]) has been finally evolved, but in *Callionymus* it appears to go no further in this direction. As it seems to me a primarily aposematic feature has been seized upon and intensely developed, by the aid of a coloration perhaps resulting from a primarily adventitious excretory process, by a sexual selection acting, as befits the environment, rather in the direction of conspicuousness than of æsthetic charm[3]. A term, "sematepigamic," must perhaps be coined to suit the present condition.

If Stolzmann is right in considering the dances of male birds, not as a peaceful strife, but as a distraction to protect the female againt the too constant attentions of the male, the same interpretation can hardly be placed on the courting antics of the male Dragonet. For here the only difficulty which appears to be felt by the female is to get as much male society as she wants.

Unless the female is degenerate, which I do not think we are entitled to assume, the free use by the male of his special characters for aposematic purposes appears to be of secondary origin; or, perhaps more justly, the male simply continues the aposematic demonstrations of his youth with apparatus that, fortunately for himself, has been improved by a sematepigamic process of selection. Beddard[4] has suggested that similar, but not sexually-differentiated structures, the enormous pectoral of *Dactylopterus* and the dorsal fin of *Thymallus*, may be effective in diverting the attack of an enemy to a non-vital part. This is possibly the case, since we have seen that one male Dragonet struck at the first dorsal of another. The tub-gurnard (*Trigla hirundo*) furls its large and beautiful pectorals when at rest; but they are instantly expanded if the fish is molested, and are kept expanded when the fish is driven about or is simply swimming round the tank undisturbed. The John Dory instantly erects the dorsal filaments when alarmed, and these are supported by very powerful spines. On the whole it appears most probable in the two cases last mentioned and in the Dragonet

[1] I have observed that Pike (*Esox lucius*), when quarrelling, menace each other by inflating the whole gill-apparatus. In its natural environment it must be long since the Pike was associated with any object of mimicry more formidable than itself.

[2] *Cf.* Poulton, *op. cit.* p. 271.

[3] Though it is possible that the brilliant coloration was originally acquired in shallow water, where details could be more readily appreciated.

[4] *Op. cit.* p. 191. Messrs. W. L. Calderwood and G. P. Bidder have told me that when a *Dactylopterus* was placed in a tank at Naples containing some small sharks, the latter bit pieces out of its pectorals, a liberty resented by violent grunting. Gurnards and dories also grunt under circumstances of discomfort, the sounds being of the nature which appears from experiment to be perceptible by fishes. They may possibly subserve a function which is in part protective.


BRITISH MUSEUM
NATURAL HISTORY